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6. AUTHOR(S)

Peter Kirstein

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University College London
Gower St
London WC1E 6BT
UK

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

DARPA Information Technology Office
ATTN: Tim Gibson
3701 Fairfax Drive
Arlington, VA 22203-1714
USA

Office of Naval Research
Boston Regional Office
ATTN: Richard Ortisi
495 Summer Street
Boston, MA 02210-2109, USA

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14. ABSTRACT

This is the final report for the DARPA-funded Radioactive Project, covering the period July 1999 – December 2003. We pursued three objectives in the project. The principal one was to demonstrate use of IPv6-enabled Active Services at natural boundaries between network technologies; this was to be Application Level Active Network (ALAN), as distinct from the other Active Networking technologies under the DARPA programme. The second objective was to investigate various technologies – in particular mechanisms for providing Quality of Service (QoS). The third was to support the International Collaboration Board (ICB), of which Prof Kirstein has been the Chair throughout the period of this project; in this context considerable work was done in providing IPv6-enabled VPNs in a manner suitable for deployment in the ICB environment.

As part of the DARPA Active Networks programme, the contractors were encouraged to collaborate with others on the programme to make joint demonstrations. The principal demonstration pursued under the first of the above objectives was for demonstrating IPv6-enabled interactive multicast, wide-area, multimedia conferencing over the Xbone as developed by Joe Touch in the Dynabone project. This was demonstrated at the DANCE meeting between intercontinental-separated sites.

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Final Report

Peter Kirstein

Department of Computer Science, University College London

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Abstract

This is the final report for the DARPA-funded Radioactive Project, covering the period July 1999 – December 2003. There were three objective of the project. The principal one was to demonstrate use of IPv6-enabled Active Services at natural boundaries between network technologies; this was to be Application Level Active Network (ALAN), as distinct from the other Active Networking technologies under the DARPA programme. The second objective was to investigate various technologies – in particular mechanisms for providing Quality of Service (QoS). The third was to support the International Collaboration Board (ICB), of which Prof Kirstein has been the Chair throughout the period of this project; in this context considerable work was done in providing IPv6-enabled VPNs in a manner suitable for deployment in the ICB environment. Each of these is considered in turn.

As part of the DARPA Active Networks programme, the contractors were encouraged to collaborate with others on the programme to make joint demonstrations. The principal demonstration pursued under the first of the above objectives was for demonstrating IPv6-enabled interactive multicast, wide-area, multimedia conferencing over the Xbone as developed by Joe Touch in the Dynabone project. This was demonstrated at the DANCE meeting between intercontinental-separated sites.

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1 Introduction and Background

1.1 Introduction

This is the final report for the DARPA-funded Radioactive Project, funded over the period July 1999 – December 2003.

There were three objective of the project. The principal one was to demonstrate use of Active Services at natural boundaries between network technologies; this was to be Application Level Active Network (ALAN), as distinct from the other Active Networking activity under the DARPA programme. We stated that we would establish a flexible and useful infrastructure, based on middleware provided in other projects, show usability with some applications incorporating security considerations and IPv6, and demonstrate a total system with a useful functionality. The second objective was to investigate Quality of Service (QoS) routing; this was because it was one of the possible applications of the ALAN technology. The third was to support the International Collaboration Board (ICB), of which Prof Kirstein has been the Chair throughout the period of this project. Each of these is considered in turn.

The initial proposal [Crow1] had Jon Crowcroft and Peter Kirstein has co-Principal Investigators. This is reflected in the joint authorship of the first three progress reports [Crow2] – [Crow4]. In September 2001, Jon Crowcroft moved to Cambridge University. At this time Peter Kirstein took over the full running of the project. This is reflected in the authorship of the subsequent progress reports [Kirs2] – [Kirs5].

1.2 Organisation of the Report

This report is organised as follows. We first review, in Section 2, the work done on ALANs. In Section 3, we then consider the QoS activity. One part of the original proposal was work on secure networks. A major application treated in Section 2 was the establishment of dynamic VPNs. For the International Collaboration Board (ICB), this area was also considered important; our work here is described in Section 4. In addition, we chaired and serviced the ICB the meetings themselves; in Section 5, this activity is described. We consider briefly publications and honours in Section 6. In Section 7, we review the use of resources. Finally, extensive references are given.

2 Application Level Active Networking

2.1 The Initial Plan

In the original proposal we stated that the main objective of this project was to show how Application Level Active Services could be used to provide important new functionality in computer networks. The main emphasis was to be on the demonstration of the added functionality that can be achieved; of particular importance in this context are application-level routing, packet forwarding with DiffServ, and mechanisms for the location of key modules.

Since the total manpower on the project amounted to only one research and one graduate student, there were severe limitations on what could be tackled. It was intended from the beginning that this work would be complementary to other projects at UCL in this field – in particular work on Active Networks under the ANDROID Project, funded by the European Commission (EC).

2.2 The Implementation

There were several distinct phases of the project. We had decided early on that we would use multimedia conferencing as an application in the project. During the first few months, we ensured that the conferencing would work in a securable form. This was partly to allow us to ensure that the conferencing

software was in a suitable form for its later use in an IPv6-enabled form. It was partly to provide a paper [Kirst1] for DISCEX-2, which marked the termination of one of the projects in which our earlier work had been done. The basic software we intended to use for the Active Networking was at the Application Level (ALAN). A second strand was to ensure that the basic implementation of ALAN, called FunnelWeb [Ghosh], worked well and could be IPv6 enabled. Both these phases of the activity were common to the ANDROID and RADIOACTIVE projects; both intended to use the same ALAN infrastructure, the same applications and the same versions of IPv6.

At this point there was a significant divergence between ANDROID and RADIOACTIVE. ANDROID had partners in two commercial entities BT and 6WIND. The former was concerned in providing a middleware component that handled all the external communications, management of the ALANs, and billing databases. The latter was concerned with the facilities that could be put in edge routers. By contrast, Doug Maughan, the DARPA Active Networks Programme Manager, was concerned in having different contractors in the programme collaborating in joint activity and joint demonstrations. This had two impacts from the UCL viewpoint. For reasons of Intellectual Property and even timescales, it was impractical to include in the RADIOACTIVE system any components from the other ANDROID contractors. Secondly, we had to find another contractor under the DARPA programme with whom we could collaborate. Luckily, there was an important application that was common to both programmes – Virtual Private Networks (VPNs). These were treated quite differently in the two cases. In ANDROID, the VPNs were actually constructed in the edge routers; a major part of that project was the management of the VPNs under yet another contractor Netcelo [Carl2]. The functionality of a UCL server near the edge of each LAN of the wide-area network was to provide Unicast-Multicast conversion, provide bandwidth limiting (via the Transcoding Active Gateway (TAG)), and to invoke the management system to set up the (Unicast) VPNs. Once the VPNs had been set up, the UCL conferencing system operated in multicast mode over the LANs, and could invoke other sites to join the conferences – or set up streaming servers.

In ANDROID, making the Netcelo management system and the 6WIND routers IPv6-enabled was a major part of the work. We had to make our server compatible with their dialogue. In RADIOACTIVE, we teamed up with Joe Touch at ISI, who had developed the Xbone hierarchic VPN system [Touch] under the programme. Here we had two challenges; the first was to interact with his management system and VPNs, the second was to make his system IPv6-enabled. By the time of the Atlanta PI meeting in November 2000, we had succeeded in demonstrating the UCL applications in IPv4 mode over Xbone VPNs set up manually [Crow3]. While not too major a step in automation, it did demonstrate compatibility, showed the whole system working over intercontinental WANs, and identified what components would require automation. Joe was interested in IPv6, but was not tasked to do this at the time. In the subsequent 18 months, we made his system as IPv6-enabled as was feasible from outside; that meant that while the lowest level of physical communication between the Xbone system and ours was still IPv4, all the VPNs and the UCL applications were IPv6. We automated all the aspects of communication between the Xbone and our servers, and automated the resource discovery. At the DANCE conference and exhibition in May 2002, we were able to demonstrate a multi-site, IPv6-enabled, active network-based, intercontinental conference system over the Xbone [Kirst5], [Kirst6].

With that demonstration, the experimental part of our collaboration with ISI in this activity ended. We continued the development of the UCL components like the TAG in the ANDROID context, and were able to demonstrate a similar functionality over a full IPv6 network with dynamic VPNs at the IST meeting in Copenhagen in November 2002.

While our collaboration with ISI stopped in the context of this activity, it has continued in the context of the VPN work of Section 4. Since ISI has now done all the work of making the Xbone properly IPv6-enabled, it would now be possible to run the ANDROID demonstrations in full over the XBONE. In practice it is probable that further adaptation would be needed to make this demonstration in practice, because various of the underlying environments and their interfaces have probably changed over the last year.

2.3 Meeting the Objectives

The original objectives included the following:

- Application Level Routing, with multimetric criteria
- Inter-domain proxylet Services (including Receiver-driven Layered Congestion Control (RLC) algorithms
- Dynamic Reservation Protocols
- Object Location Services
- Security Services

Many of these were demonstrated above, including application level routing, inter-domain proxylets, and object location. However some these were only done as protocols by themselves, and not in the demonstrations of this section. This was because the basic technologies to be demonstrated were changed as a result of the subsequent request for collaboration with other partners. In some cases, like the multimedia recorder [Lamb1] and the transcoding active gateway [Kirs7], proxylets were developed and shown in the demonstrators. For the Security Services, we concentrated on VPNs.

3 Basic Technologies

Many basic technologies – particularly for QoS – were examined theoretically and experimentally.

The Quality of Service algorithms were presented in several papers – in particular [Bris], [Carl2], [deMeer] and [Gevr1]. It was originally intended that these would be made into Proxylets, and demonstrated in the work of Section 2. In practice the change of direction implied by the integration of the UCL work with the ISI one did not allow this to be done. The Transcoding Active Gateway [Kirs7] showed another aspect of QoS, since this allowed bandwidth to be constrained in the wireless part of a network, and so the quality of audio and video to be maintained.

The multimedia recording work of [Lamb1] was suitable for pursuing in its own right as a technology, and also demonstration as Proxylets. It was not shown during the DANCE demonstrations, but was shown in the later ANDROID ones.

4 Virtual Private Networks

4.1 Activities

One task in the original proposal was to investigate Virtual Private Networks – particularly in the context of Active Networks. Another was to support the International Collaboration Board (ICB). In both the ANDROID project and the work of Section 2, VPNs were a prime application for the demonstrators. In discussions inside the ICB, in 1999, IPv6-enabled VPNs were identified as a key interest by the ICB members. In view of this, we continually reported on our VPN work to the ICB; we also invited both ISI and Defence Research and Development Canada, who were doing related work, to report on their work to the ICB. By 2002, it had become clear that the ISI work on Xbone ([Touch] funded by the US ICB member (Doug Maughan and under Joe Touch) and the Canadian work on Dynamic VPN Controller [DVC] funded by the Canadian ICB member (Vince Taylor and under Joe Spagnolo) were prime candidates. In addition the VPN and Public Key Infrastructure activity of the University of Murcia [Mart], pursued in collaboration with UCL under the aegis of the Euro6IX project was directly relevant.

During the period of this report, we have held two workshops at UCL [Lad1] and [Lad2]. The second was attended by all countries active in the ICB except the US – and there Joe Touch participated from the IETF in Minneapolis by Teleconference. The problem was that we had been obliged to schedule the meeting in the middle of the IETF. The first workshop identified the current status of the Xbone, DVC and the UMU

Public Key Infrastructure (PKI), and what needed to be done to achieve commonality between the different implementations. We agreed to take certain steps to achieve the convergence. The second, four months later and in juxtaposition to the ICB meeting, reviewed the progress, outlined the next steps, and presented the results to the International Collaboration Board (ICB). Now NRNS, ISI and UMU are all committed to providing their forms of VPN. We will continue to work with all three – under the aegis of the 6NET project. As a result, we expect to be able to deploy several forms of IPv6-enabled VPN to the ICB sites.

5 ICB Work

5.1 ICB Meetings and Web Site

We continued to service the International Collaboration Board (ICB) and act as its Chair. During the period of the project, we held nine ICB meetings:

45 DND,	Ottawa, Canada
46 FGAN,	Bonn, Germany
47 UCL,	London, UK
48 DARPA,	Washington, USA
49 DSTL,	Malvern, UK
50 DRDC,	Ottawa, Canada
51 NC3A,	The Hague, Netherlands
52 DARPA,	Washington, USA
53 UCL,	London, UK

UCL has been running a protected web site https://www-secure.cs.ucl.ac.uk/icb/ for all ICB documents. During the RADIOACTIVE project, we decided that this web site should be improved. We have put all documents related to the ICB meetings on the site – including the minutes of most of the meetings back to the late '80s. We also continued to provide minutes for the meetings. In improving the web site, we were greatly aided by the ICB members – in particular John Laws of the UK Ministry of Defence.

The semi-annual ICB meetings continue to be well attended by most of the members, who find the material presented of considerable interest – and complementary to that provided in other meetings like the official NATO and TTCP ones. The DARPA Programme Manager responsible for the RADIOACTIVE Project has been the ICB member from the US. For the last three years, the DARPA member has not been able to attend the meeting outside North America. At the 53rd meeting in November 2003, all the current ICB members were present except Germany and the US. At that meeting, it was decided that the continued presence of DARPA at the meetings, and the implied support given by DARPA to the ICB activities, were vital to several of the partners being able to get continued funding from their Ministries of Defence. It was agreed that Prof Kirstein was to discuss this situation with the current DARPA ICB member, Tim Gibson; if the relevant US attendance could not be assured, then it was considered desirable to wind up the Board. This matter is being discussed between Prof Kirstein and Tim Gibson.

6 Publications and Honours of PI

We note that under the terms of the contract, we are supposed to inform the Programme Manager of any honours received by the Principal Investigators and of any publications.

6.1 Honours

As regards Honours, Peter Kirstein received the following awards during the period of the RADIOACTIVE project:

- The ACM Sigcomm award in 1999
- The IEE Senior Award in 1999
- Election as a Foreign Honorary Member of the American Academy of Arts and Sciences in 2002
- Commander of the British Empire in 2003
- Postel Award in 2003

6.2 Doctoral Theses

Three theses arose out of the work done in this project – though they started under the previous DARPA-funded project [Crow1]. The three are:

[Brown] Brown, I: "End-to-End Security in Active Networks", PhD Thesis, Department of Computer Science, University College London, September 2001.

[Gevr2] Gevros, P "Congestion Control Mechanisms for Scalable Bandwidth Sharing", PhD Thesis, Department of Computer Science, University College London, August 2003.

[Lamb2] Lambrinos, L: "Distributed Approach to Multicast Multimedia Conference Recording and Playback, PhD Thesis, Department of Computer Science, University College London, December 2003.

6.3 Publications

[Carl1] Carlberg, K, P Gevros and J Crowcroft: "Lower than Best Effort: a Design and Implementation", Workshop on Data Communications in Latin America and the Caribbean, 3-5 April 2001 San Jose, Costa Rica.As regards publications, the following have appeared during the period of the project:

[DeMeer] De Meer and P. O'Hanlon: "Segmented Adaptation of Traffic Aggregates", to appear in IEEE IWQoS 2001.

Gevros] Gevros, P et al: "Congestion Control Mechanisms and the Best Efforts Service Model", IEEE Networks, 2001.

[Ghosh] Ghosh, A., M. Fry and J. Crowcroft:"An Architecture for Application Layer Routing"; Yasuda, H. (Ed), Active Networks, LNCS 1942, Springer:pp. 71–86. ISBN 3-540-41179-8 Springer-Verlag, October 2000.

[Kirs1] Kirstein, PT, E Whelan and I Brown: "A Secure Multicast Conferencing", DISCEX 2000, pp 54-63, IEEE Computer Society, 2000.

[Kirs7] Kirstein, P et al.: "Media Transmission over Coupled Wired/Wireless Networks using Applications Level Active IPv6 Networks", Proc. Converged Networking – Data and Real-time Communications over IP, Interworking 2002, Kluwer Academic Publishers, pp 197-211, 2002.

[Kirs12]: Kirstein, P, M. Lad, A. Skarmeta, G. Martinez, J. Touch, S. Zeber and J. Spagnolo " Dynamic IPv6-based Virtual Private Networks", Global IPv6 Launch, Brussels, January 15-16, 2004.

In addition there were several contributions to the IETF.

7 Use of Resources

7.1 Staffing

While the funding from DARPA under the RADIOACTIVE Project has funded some of these activities, it has not been a very high proportion. This is partly because the project is only funded for one research student.

The UCL staff associated with the RADIOACTIVE project have been:

- Jon Crowcroft – Co-PI
- Peter Kirstein - Co-PI
- Ian Brown – Working on Secure End-to-End flow crossing active boundaries
- Ken Carlberg – working on the Proxylets and master minding the demonstrations
- Panos Gevros – working on the QoS
- Kris Hasler has been developing the TAG
- Manish Lad working on VPNs
- Lambros Lambrinos working on the Distributed Recording
- Piers O'Hanlon working on the Proxylets and Multimedia and several of the demonstrations

7.2 Travel

The project played a major part in facilitating the travel of the project participants outside Europe. Thus all the attendance at the ICB meetings listed in Section 5 were supported by DARPA. So were the demonstrations at Atlanta and San Francisco, the attendance at the DARPA Active Network PI meetings, and the attendance at many of the conferences at which the presentations of Section 6.3 were given.

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[Carl2] Carlberg, K et al.: "ANDROID Active Networking Architecture", Technical Report, June, 2001,

[Crow1] Crowcroft, J et al: "Mechanisms for Supporting and Utilising Multicast Multimedia-SCAMPI, Proposal to DARPA for an extension to D079", Principal Investigators Jon A. Crowcroft and Peter T. Kirstein, Department of Computer Science, University College London, June 1999.

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[Crow3] Crowcroft, J et al: "DARPA Radioactive Project, Year 2 First Semi-Annual Report, August 2000 – February 2001", Department of Computer Science, University College London, March 2001.

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